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A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs. The Bulletin *also reports on international programs in geophysics and space science that have grown out of the IGY, and on their results.*

Coupling of Air and Ocean Waves

The following material is based on a more complete report by W. L. Donn and W. T. McGuinness, of the Lamont Geological Observatory, Columbia University. The original report appeared in the Journal of Meteorology, *October 1960.*

Examination of sea- and shore-based wave and air-pressure records accumulated during the IGY at stations in the vicinity of New York City indicates that some long-period sea waves result from resonant transfer of energy from atmosphere to ocean. This coupling, involving air waves associated with a frontal disturbance and gravity waves in the ocean moving outward from the shore, produced, in the area studied, long-period sea waves having amplitudes more than 100 times greater than such air-pressure oscillations would be expected to produce under equilibrium conditions.

The investigations described were carried out under the direction of the Lamont Geological Observatory as part of the IGY Oceanographic Island Observatory Program. Lamont supervised the Atlantic Ocean portion of the United States program. Background information on this program is given in *Bulletin Nos. 2, 6,* and *9; Bulletin Nos. 16* and *22* contain some of the earlier results.

Stations and Instrumentation

As part of the IGY Island Observatory Program in the Atlantic, a long-period ocean-wave recorder and a microbarovariograph (a sensitive atmospheric-pressure recorder) were installed on Texas Tower No. 4, at 39° 48′ N, 72° 40′ W, on the continental shelf about 80 miles southeast of New York City (see Fig. 1). (Texas Tower No. 4 was destroyed in a severe storm on January 15, 1961.) The microbarovariograph, which responds to the rate of change of atmospheric pressure, was located in a shelter on the tower platform, about 90 feet above the water. (*Bulletin No. 9* contains a description of the instrument.) The pressure-sensitive wave recorder con-

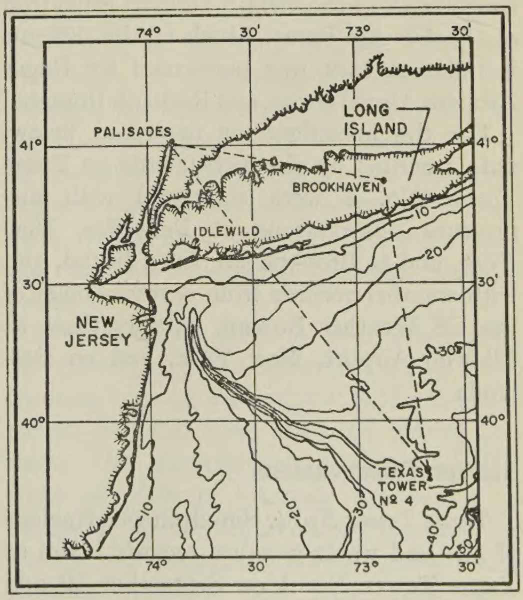

FIG. 1. *Region of Study of Air-Ocean Wave Coupling. Water depths shown in fathoms.*

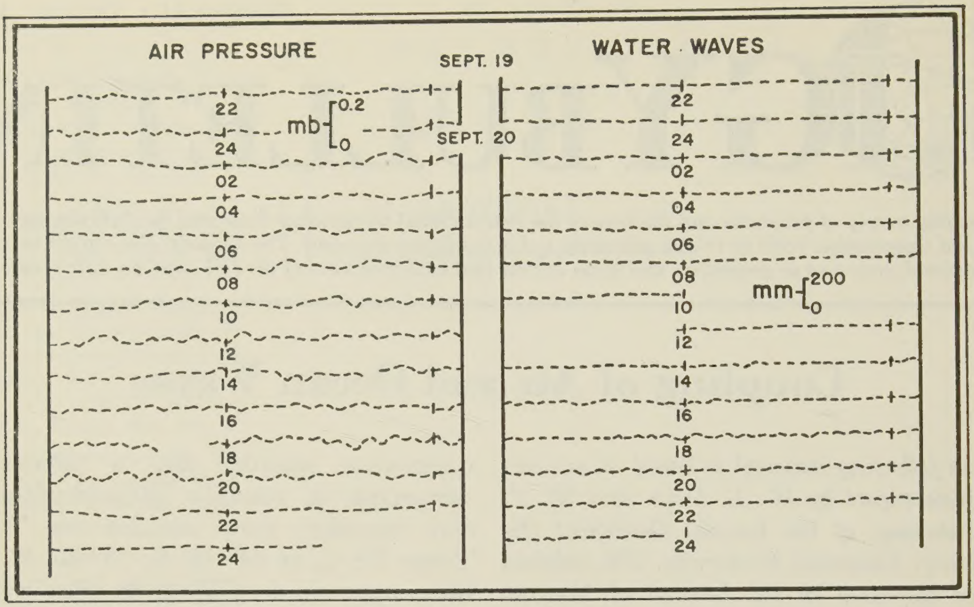

FIG. 2. *Records of Air and Water Pressure from Texas Tower No. 4 for the Period 2200 EST September 19—2400 EST September 20, 1958.*

sisted of an underwater pressure head secured to a vertical cable at a depth of 30 feet, and a sheltered amplifier and recorder.

The instruments were installed and maintained on the Texas tower through the cooperation of the 4604th Support Squadron of the US Air Force. Much of the difficult installation task was performed by Roger Zaunere, David Owen, and Rudolph Romano.

For the investigations described below, data recorded by the instruments on Texas Tower No. 4 were compared with air-pressure observations at Palisades, New York, and at Brookhaven, Long Island, and with weather records from several offices of the US Weather Bureau, notably those at Idlewild Airport, New York, and on Bermuda.

Station Observations

Texas Tower No. 4: Simultaneous tracings of air- and water-pressure records taken at Texas Tower No. 4 on September 19 and 20, 1958, are shown in Figure 2. Each line represents a two-hour period, and absolute time (EST) is labeled every hour. Increasing pressure is shown by an upward movement on both traces; hence, the trace for water waves indicates actual sea-level configuration.

Although simultaneous oscillations can be detected on both air and water records as early as 0200 September 20, this relationship becomes much more distinct between 1400 and 2000, when amplitudes on both records are greatest. During this interval, maximum air-pressure oscillations reached 0.05 millibars (1 mb = 1000 dynes/cm^2, or 1/32 inch Hg; sea-level air pressure = 1.0132×10^6 dynes/cm^2, or 29.92 inches Hg), and ranged from about 0.01 to 0.05 mb. Maximum sea-level oscillations varied from about 15 to 40 mm.

Under conditions of equilibrium, sea-level changes corresponding to the recorded air-pressure variations would reach a maximum of 0.5 mm of water. Actual sea-level changes recorded from 1400–1600 and 1700–1900 hours, however, showed oscillations as much as 115 times greater than the barometric equilibrium waves (Table 1), strongly indicating a dynamic magnification beyond

Table 1. Actual sea-level changes as determined from Texas Tower No. 4 records for 1400–1600 and 1700–1900 hours, September 20, 1958.

Time interval	Mean amplitude of air-oscillations (mm sea water)	Mean amplitude of water oscillations (mm)	Magnification
1400–1600	0.17	13.8	81
1700–1900	0.28	32.2	115

the equilibrium effect. (Note that air pressure is expressed in the table in millimeters of sea water, thus giving directly the mean values of the barometric equilibrium waves in the sea.)

Examination of the records indicates that both the air and water oscillations are slightly dispersive (i.e., wave period decreases with time or velocity). Moreover, Figure 3, a plot of arrival time against wave-crest number for simultaneous air and water waves, clearly shows a similarity between the dispersion in both media.

It seems evident from the data presented above, and particularly from Table 1, that the simple equilibrium barometric effect is not adequate to explain the magnitude of the observed water oscillations. A possible seismic origin for these waves was ruled out after a detailed study of all earthquake reports for about this time. It thus appears that somewhat special conditions existed, which provided a mechanism for the transfer from air to water of energy well in excess of that of equilibrium conditions.

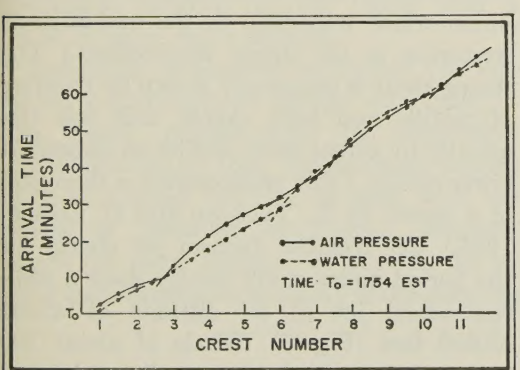

Fig. 3. *Dispersion Curves for Air and Water Oscillations. Wave-crest numbers are plotted against time, which is shown in 10-minute intervals from 1754 EST September 20, 1958. Although dispersion is slight, it is clearly similar in both curves.*

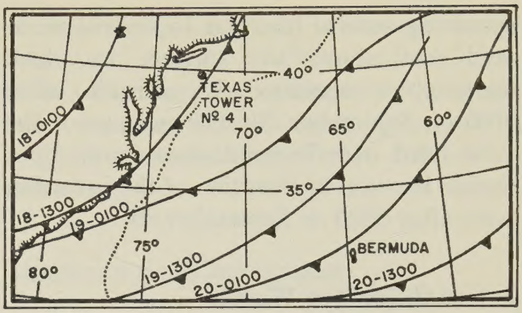

Fig. 4. *Position of Cold Front at 12-hour Intervals between 0100 EST September 18 and 1300 EST September 20, 1958.*

Palisades, New York: Pressure oscillations similar to those recorded at Texas Tower No. 4 were also recorded on the mainland, at Palisades, during about the same time interval. Although fairly strong oscillations are present in most of the Palisades record, those of short period (about 5 to 10 minutes) became much more prominent from 1000 to 1600 hours, at about the same time as at the tower. In addition, definite continuity of a more gross barometric oscillation was recorded at about 2400 on September 19 by microbarographs at Palisades, Brookhaven, and Texas Tower No. 4. The lack of precise timing on these compressed records does not permit velocity determinations, but this event clearly occurred first at Palisades.

Meteorological Data: It was noted from the meteorological records that a cold front (leading edge of a relatively cold air mass) passed seaward over the area during this time. The approximate positions of this front at 12-hour intervals are shown in Figure 4. As the front moved seaward, its surface was indicated by weather records at Idlewild Airport, near New York City, which show a progressive lifting of the temperature inversion (layer of air, generally

appearing several hundred to several thousand feet above the surface, in which temperature increases with altitude) after 0700 on September 19. The passage of the same front over Bermuda was shown by a similar increase in elevation of the inversion layer after 0800 on September 20.

Internal Surface Waves

A detailed investigation involving tripartite detection and orbital wind variations conducted at both Palisades and Brookhaven has established that oscillations of this type are very often waves moving along some meteorological discontinuity within the atmosphere. (P. Milic, in 1956, discussed in detail the criteria for the existence of surface-pressure perturbations; use of these criteria made possible the barometric detection of the internal surface waves observed at Palisades and Brookhaven.) Also, the currently unexplained dispersive nature of these air oscillations is a common feature of surface waves in a layered medium. It thus appears that the atmospheric-pressure oscillations described above were the ground-level manifestations of internal waves probably traveling on the frontal discontinuity.

It is possible to compute the theoretical phase velocity of these internal surface waves on the basis of vertical synoptic data. By using Idlewild radiosonde information, the average height of the inversion layer at 0700 on September 20 was found to be 2000 meters (6560 feet). The temperatures above and below the discontinuity were 283°K (50°F) and 276°K (37.4°F), respectively. Based on the equation for phase velocity of internal waves on an interface within two incompressible fluids, the computed wave velocity relative to the ground is 45 knots, or about 52 mph (E. Gossard, in 1956, obtained similar velocity results by applying this procedure to conditions in Southern California.)

It is suggested that these waves originated in perturbations produced by strong vertical wind shear (variations in wind velocity with altitude) at a much higher level. Very regular pressure oscillations are often recorded by instruments at the Lamont Geological Observatory when the jet stream is present aloft. (The jet stream is a relatively narrow, quasi-horizontal band of maximum winds imbedded in the mid-latitude westerlies in the upper troposphere.) The strong shear is commonly shown by banding of middle and high clouds, and less frequently by actual wave profiles on somewhat lower clouds. (This phenomenon is discussed in a report by K. Tillotson and D. Colson, 1954.) US Weather Bureau jet charts for the period under study clearly show a well-established jet at an altitude of about 35,000 feet (Fig. 5). Winds of about 100 knots (115 mph) became well established in the area of the study toward the latter part of September 20; as shown in Figure 2, the strong 4- to 10-minute air waves also became best developed at this time of maximum vertical shear.

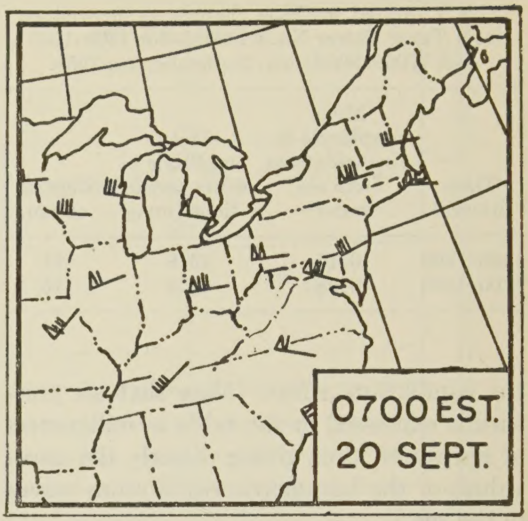

Fig. 5. *Chart of Winds at 35,000-foot Level over the Northeastern United States at 0700 EST September 20, 1958, Indicating Existence of Jet Stream. Arrows appear to fly with the wind; tail barbs represent a wind speed of 10 knots, flags a speed of 50 knots.*

Wave Coupling

The existence of air waves and simultaneous ocean waves having the same period but much greater amplitudes than those of equilibrium barometric waves, strongly suggests the resonant coupling (the coupling of systems having identical wave characteristics) of energy from air to ocean. The evidence also strongly suggests that a dynamic magnification of the water waves occurred. In order to support the theory of resonant coupling, however, it is necessary to show not only a similarity of period, but also of phase velocities of both the air and water waves over a significant fetch—or distance the wind blows over the water in a particular direction.

An average velocity of 40–45 knots for the observed air waves seems reasonable. The possible velocities of long gravity waves in the water are controlled by the depth of water between the coast and the tower. It can be seen from Figure 1 that the slope of the continental shelf from shore to Texas Tower No. 4 is uniform and gentle, with a west-to-east depth profile ranging from 60 to 180 feet. The corresponding range of gravity-wave velocities for these depths is 33 to 46 knots, which well overlaps the possible air-wave velocities. Because of the gentleness of the slope, it seems reasonable to expect resonance between air and water over a fetch of many wave lengths.

Assuming undamped conditions (no loss of wave amplitude or energy with time) in the ocean, consideration of mechanical vibrations shows that the resonant amplitude is a linear function of time, with the range of observed amplitudes requiring about 10 wave lengths for growth. In an analogous experimental study of the coupling of acoustic waves in air to flexural waves in a metal bar, by F. Press and J. Oliver (1954), significant coupling occurred after only 4 wave lengths, and very strong coupling was observed after a fetch of 7 wave lengths.

Summary and Conclusions

Simultaneous air-pressure oscillations and water waves were recorded at the IGY station on Texas Tower No. 4, situated on the continental shelf about 80 miles southeast of New York City, in which the water-wave amplitudes were more than 100 times greater than the possible barometric-equilibrium waves.

The air-pressure oscillations are interpreted as perturbations produced by internal surface waves traveling on a frontal discontinuity. Observed and calculated period spectra for the most prominent and persistent air and water oscillations have peaks at about the same frequencies, between 4 to 10 minutes, and both air and water waves show nearly identical period dispersion. The dynamic magnification of the water waves beyond the equilibrium value, and their similarity to the air waves in spectral distribution and dispersion, indicate resonant coupling between the two media. Such resonant coupling was found to be possible over a significant fetch where the period and phase velocities of air and water waves appear to coincide closely.

It is suggested that, although the water waves are produced directly by resonant coupling to air waves on a frontal discontinuity, the ultimate origin of these water waves may be in the transfer of energy from the high jet stream to the sea surface.

Effects of a Severe Solar Storm on the Orbit of Echo I

The following report is based on material prepared by Robert Jastrow, Chief, Theoretical Division, Goddard Space Flight Center, National Aeronautics and Space Administration, and Robert Bryant, also of Goddard's Theoretical Division.

Recent studies of variations in the orbit of the Echo I satellite (1960 Iota 1) have revealed that on November 12, 1960, at approximately the time of occurrence of a severe storm on the surface of the sun, the atmospheric drag acting on the satellite suddenly increased about twofold, causing a corresponding decrease of two seconds per day in the satellite's orbital period. The drag remained at this high value for several days before returning to its previous level.

Echo I, a passive communications satellite designed to reflect back to earth radio waves beamed at it by powerful transmitters, was launched by NASA on August 12, 1960, into an almost circular orbit with an average altitude of approximately 1000 miles above the earth (see *Bulletin No. 39*).

Solar radiation pressure has caused the satellite's perigee to decrease by about 2½ miles per day, reaching a minimum of about 580 miles on December 28, 1960. In January 1961, perigee was rising again under this influence (as perigee then occurred when the satellite was on the side of the earth opposite the sun) and on January 22 it was 618 miles above the earth. This oscillatory motion will continue until, at a future minimum, atmospheric drag will dominate and the satellite will cease to orbit.

The Solar Storm

The solar storm of November 12 was the most severe since the great flare of February 23, 1956. It consisted of two giant flares on the surface of the sun and several smaller eruptions, all within a period of a few days.

The sun's atmosphere boils and churns at times of unusual solar activity, producing disturbances that are analogous to bad weather on the earth. Thus, solar physicists have begun to refer to this activity as "solar weather." Occasionally, these storms on the sun produce the great eruptions known as flares, which spray charged particles, X-rays, and other kinds of radiation through the solar system.

When the particles and radiation reach the earth they have a number of effects: (1) they increase the number of charged particles in the atmosphere, and this, in turn, weakens and distorts transmission of radio waves through the ionosphere (the November 12 storm blacked out international radio communications for two days); (2) they produce storms in the earth's magnetic field; (3) they produce brilliant auroral displays; and (4) they partially empty and re-fill the Van Allen belts of charged particles trapped in the geomagnetic field, a phenomenon not yet entirely understood.

Figure 6 shows the effects of increased atmospheric drag on the orbit of Echo I as a result of the large solar flares of late November and early December 1960. The greater drag on the satellite, caused by increased atmospheric density along its path, is indicated by corresponding sudden increases in the rate of change of the orbital period.

Cause of Drag Increase

Jastrow and Bryant believe that the most likely cause of the increase in the drag acting on Echo I is an increase in the average density of the air through which the satellite travels. This increase in atmospheric density is produced when particles and

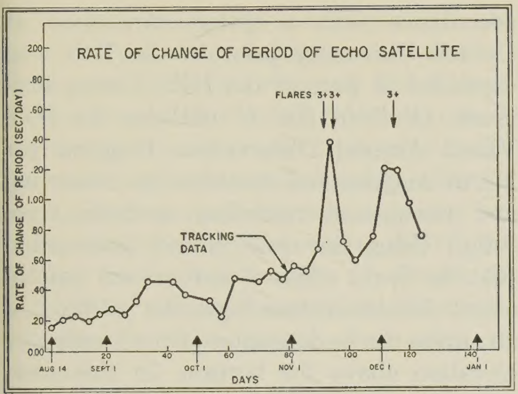

Fig. 6. *Sudden Increases in the Rate of Change of the Orbital Period of Echo I in Late November and Early December, 1960, with the Occurrence of Strong Flare Activity on the Sun.*

radiation from solar flares strike the atmosphere and heat it. The heating results in a slight outward expansion of the atmosphere at lower levels, and, consequently, a great increase in the density of the very thin air at the high altitude at which Echo I travels around the earth.

Previously, scientists at the Smithsonian Astrophysical Observatory at Cambridge, Massachusetts, and in Germany and England, had discovered that the entire upper atmosphere rises and falls, or "breathes," in response to the general level of storminess on the surface of the sun. The response of a satellite to a specific solar flare has been detected only once before, however—in 1959, in the case of Sputnik III. It has not been detected in the orbit of Vanguard I.

Echo I, as did Sputnik III, passes through the outer Van Allen belt, where, according to Explorer VI and VII measurements, the particle intensity increases as much as a thousand-fold after solar flares. Vanguard I, on the other hand, does not go through the outer belt because it is confined to low latitudes, below 33°. It is possible, therefore, that this difference in orbital paths may explain why solar storms have influenced the drag on Sputnik III and Echo I, but not on Vanguard I.

Conclusions

Jastrow and Bryant believe that the detection of this solar-storm effect on the Echo I orbit may provide a clue to the actual mechanism by which solar particles and radiation heat the atmosphere. This is one of the basic problems facing physicists in their effort to understand the influence of solar weather on the earth.

Relationships between Auroras in the Northern and Southern Hemispheres

The following material is based on two reports prepared at IGY World Data Center A, Aurora (Visual), Cornell University, Ithaca, New York, and published as part of IGY General Report Number 12, Report on IGY Visual Auroral Observations, *November 1960. Both of the more-detailed source reports are concerned with comparisons of auroral activity in the Northern and Southern Hemispheres; the first, "Ellsworth Auroral Data—1957," was prepared by R. W. Fillius, C. W. Gartlein, and G. Sprague, and the second, "Some Comparisons between Auroras in the Northern and Southern Hemispheres," by R. W. Fillius. A report on observations at the IGY South Pole Station, by Gartlein, Sprague, and B. Nack, appeared in* Bulletin No. 26.

Visual auroral observations at Ellsworth Station during the IGY period have helped

to determine the physical characteristics and the motions of auroras in southern polar regions, and correlations with similar data from other Antarctic stations have permitted delineation of the southern auroral zone. Comparisons between visual auroral observations in the Antarctic and observations made in North America as part of the US-Canadian IGY Visual Observation Program provide information on the simultaneity of Southern- and Northern-Hemisphere auroras and on similarities or differences in their forms and motions.

In both the Antarctic and in North America, visual observers recorded auroral information on mark-sense IBM cards in accordance with a system developed at Cornell University prior to the IGY and expanded as part of the IGY Aurora Program. (*Bulletin No. 12* outlines the IGY Visual Auroral Observation Program for North America and describes the observing and punch-card recording methods more fully.) Using the well-founded assumption that the lower edges of auroras are usually about 100 kilometers high, the latitude of an aurora can be determined from its angular elevation above the horizon. In this way, each observer can determine the locations of auroras from horizon to horizon over a total latitude range of about 9°, or about 1000 km.

A. Ellsworth Data for 1957

Visual auroral observations made in 1957 at Ellsworth IGY Station (about 78°S, 42°W), Antarctica, as part of the US-IGY program indicate that the number of auroras occurring annually at Ellsworth Station roughly approximates that of the St. Lawrence River area of eastern North America. Comparison of records from Ellsworth with those from the United States shows that on virtually all occasions when an aurora was observed at one of these locations an aurora also occurred at the other; details of their forms, however, appear to be somewhat independent.

Simultaneity of Occurrence in Northern and Southern Hemispheres

The number of days during the austral winter of 1957 on which auroras occurred simultaneously in both hemispheres, and the number of days on which such auroras displayed similar forms, are shown in Table 2. On many days, visibility was so poor that neither the occurrence of an aurora, nor its form, could be ascertained. However, on the basis of hourly reports, more than 99% of the auroras seen occurred simultaneously at both the northern and southern stations. On one occasion only, on July 3, 1957, at 0600 UT, an aurora was reported and photographed in the United States while Ellsworth reported clear conditions with no aurora.

As Table 2 shows, about half the auroras occurring simultaneously in the two hemispheres were similar in forms and in patterns of change of forms, while the other half were not. Among the latter, no common pattern was observable. On some occasions when a glow changed to a homogeneous arc

Table 2. Simultaneity and Similarity of Forms of Northern and Southern Hemisphere Auroras, Austral Winter 1957.

Month	Days With Simultaneous Auroras	Days With Simultaneous and Similar Auroras
June	12	7
July	10	2
August	13	7
September	8	6
Totals	43	22

in North America, Ellsworth reported rayed arcs and pulsating surfaces; on other occasions, conditions were reversed. These observations imply that although the aurora is a global phenomenon, the observed detailed features may be determined locally, after the solar initiating agent has separated into two parts. (*Bulletin No. 12* describes the various auroral forms; *Bulletin Nos. 12, 18, 32, 36*, and others, contain information on the relationships between auroras and solar activity.)

Location of Auroras

Although it is not yet clear just what determines the geographic position of an aurora, an attempt was made to find corresponding geomagnetic latitudes from simultaneous auroral observations in both hemispheres. Times when simultaneous arcs were observed in the two hemispheres were selected, and the latitudes of the Ellsworth observations were plotted against the latitudes of the simultaneous auroras seen at longitude 75°W in North America. The results are shown in Figure 7.

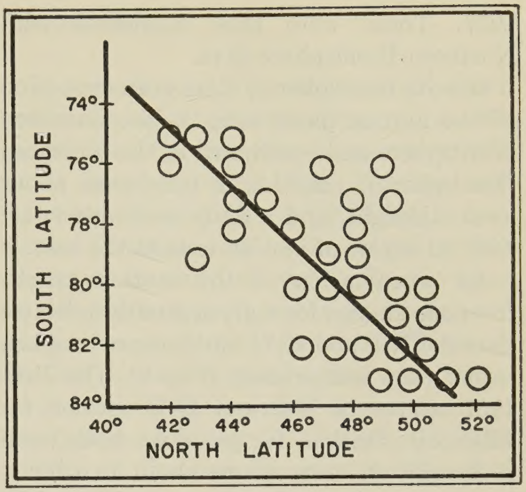

Fig. 7. *Latitudes of Simultaneous Arcs at Ellsworth Station and at 75°W in the Northern Hemisphere, 1957. Diagonal line shows geographic relation between Northern and Southern Hemisphere auroras; circles indicate roughly the precision of position estimates for auroras plotted.*

The diagonal line in Figure 7 shows the approximate geographic relation between the northern and southern portions of the aurora. (The size of the circles provides a rough estimate of the precision of determination of the auroras' positions.) If correct, the line indicates that an aurora over Ellsworth station, at latitude 78°S, will be accompanied by a corresponding aurora over Ottawa, Canada, at 46°N.

An aurora over Ottawa tends to curve northeastward and would cross Ellsworth's geographic longitude at Kap Farvel (Cape Farewell) on the southern tip of Greenland. This is presumably near the magnetic conjugate point in the Northern Hemisphere corresponding to the geomagnetic position of Ellsworth Station in the Southern Hemisphere. However, Kap Farvel is at geographic latitude 60°N, which is in twilight from May 1 until mid-August, the interval during which practically all of the observations from Ellsworth are made. Thus, the Northern Hemisphere counterparts of auroras observed in these months at Ellsworth Station cannot be seen at Kap Farvel, and the portion of the auroral zone extending below 50°N in eastern North America is the only region in the Northern Hemisphere from which good simultaneity checks with the Antarctic can be made.

The locations of the northern and southern halves of the aurora were deduced from the positions of arcs when arcs were reported simultaneously in the two hemispheres. Arcs were chosen solely because they are easiest to identify and to locate.

Auroral Motions

Visual observers report auroral motions as well as the forms present; these motion reports were examined in an effort to identify regular patterns. Plots of north-south and east-west motion in the vicinity of Ellsworth Station were made for the months of May, June, July, and August

1957. These were then compared with Northern Hemisphere data.

In both hemispheres, there is an expansion of the aurora (northward in the Southern Hemisphere and southward in the Northern Hemisphere), reaching a maximum about local midnight, and a daily east-west effect with an excess of motion toward the east.

An examination of the motion graphs from one station for a given month indicates that the N-S and E-W motions are coupled, rather than independent (Fig. 8). The June 1957 curves of N-S and E-W motion for Ellsworth Station, for example, both seem to be shifted to positions about two hours later than those for August. This shift probably results from the particular auroras observed rather than from any systematic seasonal effect, as similar shifts also occur in the May and July records of N-S motion.

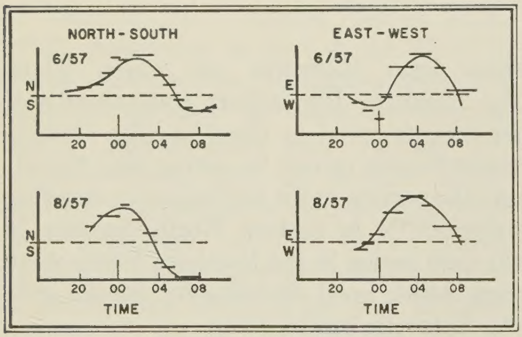

Fig. 8. *Daily Motions of Auroras Seen at Ellsworth Station in June and August 1957. Dashed line represents east-west zenith meridian in N-S graphs, and north-south zenith meridian in E-W graphs; horizontal lines are positions of auroras observed.*

The excess of eastward motion and of northward motion might suggest that they, too, are coupled. However, they are out of phase. Moreover, it seems necessary to ascribe some of the apparent motion to perspective effects, as Ellsworth Station is close enough to the geographic South Pole so that auroras located 50° of longitude (or three time zones) east or west of the station, can be seen. Thus, two observers in this

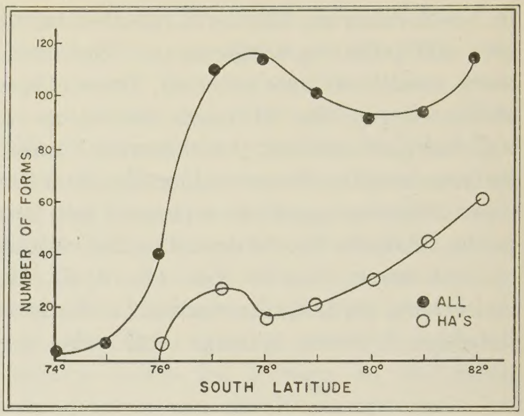

Fig. 9. *Number of Auroral Forms (dots) and Comparative Number of Horizontal Arcs (circles), plotted as a Function of South Geographic Latitude. The data were obtained by selecting reports for the intervals within two minutes of the hour on nights when auroras were visible during the IGY.*

general area whose local clocks were three hours apart might see the same aurora, and the resulting time-motion curves would have significantly different values at the two stations. Some perspective effect is implied, perhaps connected with the local expansion of the aurora that typically occurs about midnight, or with deflection by the earth's magnetic field.

Location of Southern Auroral Zone

The southern auroral zone is defined as the region of the Southern Hemisphere that has the largest number of overhead auroras per year. Ellsworth visual data were analyzed to determine the location of this zone with respect to the station. Figure 9 shows, as a function of geographic latitude, the total number of forms (dots), and the number of arcs (circles), observed within two minutes of the hour. Observations at latitudes 77°, 78°, 79° S are over-weighted by a perspective effect, first noted by C. T. Elvey (1955), and those at the outer limit of the range are less reliable because of ground haze. There is no doubt, however, that the number of forms increases toward the south, and presumably the number of

auroras also increases in this direction from the station. Comparisons with a similar plot of data from the IGY South Pole Station shows that the zone must lie between the South Pole and Ellsworth Station. (See *Bulletin No. 26*.)

The position of the southern auroral zone corresponds to a geomagnetic latitude of about 68°S. The geomagnetic latitude of Ottawa, Canada, which sees the conjugate auroras in the Northern Hemisphere, is 57°N.

A tentative set of isochasms, or lines of constant auroral frequency, is shown in *Bulletin No. 26*, Figure 2. The isochasms are modified, in some manner not yet clarified, by daily and probably seasonal effects, but this modification should amount to less than 10° of latitude.

Summary

The results of IGY visual auroral observations described above may be summarized as follows: (1) An aurora occurs at the same hour in both the Northern and Southern Hemispheres. (2) The various auroral forms, as well as the stages in their development, are not necessarily the same in the northern and southern portions of the aurora. (3) Auroras seen from Ellsworth Station, in the Antarctic, are usually accompanied by a conjugate aurora over the St. Lawrence Valley of Canada. (4) The portion of the aurora seen at Ellsworth Station has its greatest expansion near local midnight. (5) The southern auroral zone passed between Ellsworth Station and the geographic South Pole in mid-1957.

B. Comparison of Northern and Southern Hemisphere Auroras

The aurora is believed to be caused by charged particles coming from the sun and becoming trapped in the earth's magnetic field. The particles are thought to spiral along lines of magnetic force to the northern and southern auroral zones, where some of them enter the atmosphere and collide with air particles, releasing energy in the form of auroral displays. If this theory is correct, corresponding auroras should occur at magnetic conjugate points—the points at the two ends of a line of force. Also, the extent of the aurora would be determined by the radius of gyration of the particles, and this gyration radius would, in turn, be determined by the particle velocity and angle to the line of magnetic force. Thus, variations might be expected between the auroral zones, and within each zone, as the earth's angular relationship to the sun changes daily and seasonally.

The following material presents the results of direct comparisons between North American auroral maps and reports from Ellsworth Station. Ellsworth Station is especially well situated for such comparisons.

Simultaneous Occurrences

Simultaneity comparisons can be made only when the observing regions in both hemispheres are in darkness. In the vicinity of Ellsworth Station, at the geographic latitude of 78°S, darkness falls during portions of days between the months of March and October, and night is continuous from May to mid-August. Gartlein, Nack, and Sprague (*Bulletin No. 26*) reported that twilight decreases auroral sightings when the angle at which the sun is depressed below the horizon is less than 18°. The maximum solar depression angle at Ellsworth Station is about 12°, and observations are difficult to make before April and after August. The longest period of good auroral visibility for Ellsworth is at the austral winter solstice, in late June; by contrast, this is the shortest night of the year in the

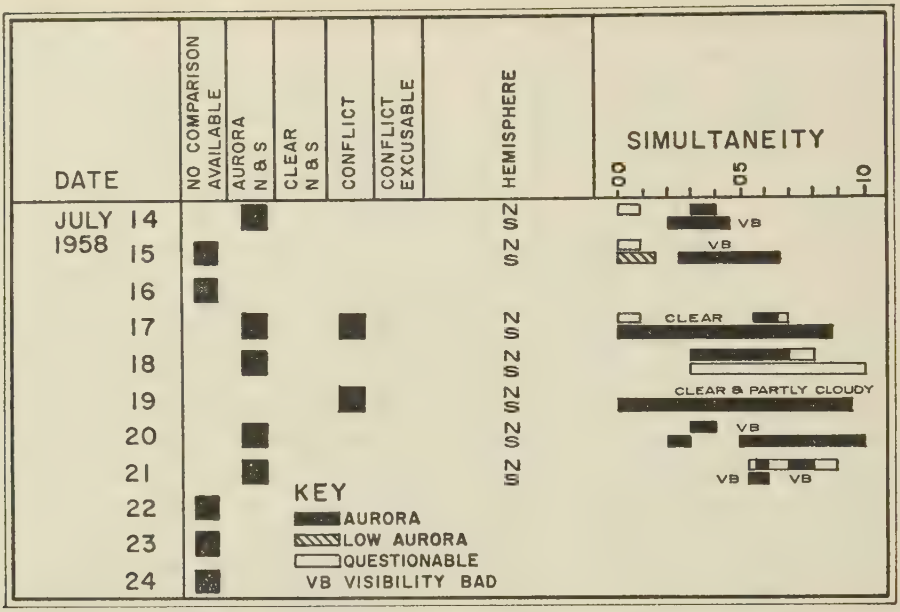

Fig. 10. *Method of Comparing Auroral Occurrences in the Two Hemispheres on a Day-to-Day Basis.*

Northern Hemisphere, where visibility of auroras is lowest in June.

Besides limitation in the number of hours of darkness, moonlight and bad weather also hampered the accumulation of visual auroral data. Poor conditions in either hemisphere made comparison impossible and, in fact, ruled out many nights entirely.

Ellsworth Station auroral data for the last six months of 1957 were checked against those for the entire United States, and it was found that, on a nightly basis, an aurora in one hemisphere was almost always accompanied by an aurora in the other hemisphere. In analyzing the 1958 data, visibility conditions were checked more throughly and Northern Hemisphere auroras occurring west of 80°W were ruled out in order to reduce any longitudinal discrepancy with observations at Ellsworth, which is at about 42°W.

A day-to-day comparison of Northern and Southern Hemisphere visual observations from March 20 to September 27, 1958, shows a total of 54 nights with corresponding auroras, two nights when both regions were definitely clear, and 20 nights with conflicting observations. (Fig. 10 is an example of the format of this day-to-day comparison.)

It is worth noting that in all of the conflicts, an aurora was reported at Ellsworth but not in the United States. Perhaps the major reason for this is that Ellsworth Station is at a higher geomagnetic latitude than the United States and more auroras are seen. Another reason, however, is that visibility was impaired on all but a very few of the occasions when an aurora was *not* seen at Ellsworth, thus preventing comparison with Northern Hemisphere observations on those occasions. Northern Hemisphere observations, on the other hand, were not so dependent on local visibility conditions as they were made over a broad network of stations.

Of the 20 conflicts, nine consisted of reports of "clear and no aurora" by observers in the United States who were located too far away from the conjugate of a small Southern Hemisphere aurora to see it. In each of the 11 remaining conflicts, at least one observer reported "clear" when the

conjugate to a southern aurora should have been visible. On five, and possibly six, of these occasions, a conjugate aurora was seen elsewhere in North America.

The investigations discussed above indicate that there is a correlation between auroral occurrences at Ellsworth Station and in North America. However, it should not be expected that every aurora will necessarily be accompanied by a conjugate aurora in the opposite hemisphere, since the comparison data showed several borderline cases and some definite exceptions.

Comparison of Forms

Comparisons indicate that the forms of simultaneous auroras in the two hemispheres frequently do not correlate with each other. On some occasions, glows occurred in the Northern Hemisphere while flames were seen in the Southern, or vice versa. Combinations such as rayed arcs in contrast to diffused surfaces, rays and surfaces to multiple arcs, and homogeneous arcs to pulsating surfaces come and go with no apparent interconnection. Hence, it appears that the forms are determined independently.

This conclusion should not be accepted without some reservation, however, as the forms do not always differ; on many days, the simultaneous auroral displays were similar in that the forms in both hemispheres were either active or inactive. Further, on one impressive occasion (April 16, 1958), previously quiet auroras in both hemispheres erupted suddenly and approximately simultaneously (within the accuracy limits of the reports) into active displays of rays, rayed arcs, and flames.

Geographic Position, Extent, and Variations

If a correspondence exists between auroras in the Northern and Southern Hemispheres, there should also exist correlations between their geographic positions and extent and in daily and seasonal variations of these factors. Attempts were made to find such correlations by plotting the data in several different ways. Graphs similar to that shown in Figure 7 were compiled to show the locations and extents of simultaneous auroras in the Northern and Southern Hemispheres, the approximate breadth of the auroral zones, and the corresponding latitudes of occurrence, in each hemisphere, of simultaneous auroras.

Graphs showing the positions of auroras at different times of the year were examined for indications of possible seasonal changes in the positions. An apparent shift is shown in 1957 from higher to lower north geomagnetic latitudes and from lower to higher south geomagnetic latitudes, but this shift is not repeated the next year. Indeed, in 1958, there appears to be a shift in the other direction. The positional shifts, then, must be related to differences in the individual auroras rather than to seasonal effects.

The simultaneous greatest extents of auroras, simultaneous arc forms, and nightly greatest extents were plotted on graphs in further efforts to identify daily or seasonal patterns. Observational data were also plotted on a yearly basis for this purpose. All of these plots showed scattering of points with no evidence of distinct patterns.

A time-of-day breakdown of 1957 data was also made, since, in such a breakdown, a shift in auroral positions can be predicted. No shift was visible, however. As the greatest extent of an aurora in each hemisphere occurs at about local midnight, auroras observed from Ellsworth Station would have their peaks near 0300 UT and Northern Hemisphere auroras observed in eastern North America near 0500 UT. From 0300 to 0500, then, the southern auroras should retreat and the northern auroras advance. No such effects are visible in the graphical data, again indicating that they are outweighed by the individual characteristics of the auroras.

Conclusions

Visual auroral observations made at IGY Ellsworth Station, Antarctica, and in North America during the IGY were compared to investigate the question of simultaneity of auroras in the Northern and Southern Hemispheres, and to determine the characteristics of such conjugate auroras—location, extent, and daily and seasonal variations.

Although a correspondence between auroral zones was determined, the peculiarities of the individual auroras obscured any seasonal and daily variations that may have occurred. This does not mean such variations do not exist, however. Over-all relations dominated the findings because the volume of data was such that finer auroral characteristics were evened out statistically. If more data or some other way of normalizing the auroral individualities are used, daily and seasonal variations may become apparent.

Status of Report Series of IGY World Data Center A

The following report is based on a detailed, annotated booklet, "List of IGY Report Series," available from IGY World Data Center A, National Academy of Sciences, 2101 Constitution Avenue, N. W., Washington 25, D. C., or from any of the subcenters of WDC-A.

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* No. 7. Interim Catalogue of Data in IGY World Data Center A. 169 pp., Nov. 1959.

* No. 8. Fifth Six-Monthly Catalogue of Data in IGY World Data Center A. 206 pp., Feb. 1960.

No. 9. IGY Meteorological Data on Microcards, compiled by William M. McMurray. 142 pp., June 1960.

* No. 10. Sixth 6-Monthly Catalogue of Data in IGY World Data Center A. 154 pp., July 1960.

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No. 12. Report on IGY Visual Auroral Observations, by Carl W. Gartlein and Gale C. Sprague. 103 pp., Nov. 1960.

No. 13. Seventh 6-Monthly Catalogue of Data in IGY World Data Center A. 229 pp., Jan. 1961. (Cumulative catalogues of data received by the eleven subcenters of WDC-A during the period 1 July 1957–31 Dec. 1960.)

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Rocket Report Series

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No. 13. Indices of the Solar Corona, July 1957–December 1959, by Dorothy Trotter. 57 pp., Dec. 1960.

No. 14. Flare Index for Each Day of IGY Based on McMath-Hulbert Observatory Working List of IGY Flares, by Helen W. Dodson and E. Ruth Hedeman. 17 pp., Jan. 1961.

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